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DEVELOPMENT OF A SAFER INTERMEDIATE AND FIRST FIRE FORMULATION FOR THE M49A1 SURFACE, TRIP FLARE

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Dover, New Jersey

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Markedly safer intermediate and first fire ignition charges were developed for the M49A1 surface, trip, flare. The ignition train of the trip flare presently consists of an M42 percussion primer which activates an adjacent intermediate charge (90/10 barium chromate/boron) which, in turn, ignites a pressed first-formulation (90/10/1 barium chromate/boron/vinyl alcohol acetate resin) that is in contact with the illuminant load of the flare. Both the present intermediate and first-fire formulations are

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sensitive to impact, frictional, and electrostatic initiation. If they were to be accidentally initiated during the loading process, they would not only burn, but also cause the subsequent ignition of the illuminant load.

A laboratory study was conducted to develop a substitute formulation closely matching the pressure-time profile and generated gas volume of the presently used compositions, but having significantly less sensitivity. A new formulation containing 65/24/10/1 tungsten/barium chromate/potassium perchlorate/vinyl alcohol acetate resin (VAAR) met these criteria and was demonstrated to be an efficacious substitute for both the older intermediate and first-fire compositions. The new formulation was designated as DP-1886. In addition to the safety factor provided by this change, a reduction of inventory and processing costs will be realized through the use of one formulation for the two different ones currently employed.

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OBJECT

To develop a new intermediate and first-fire formulation as a substitute for the ignition system in the M49A1 surface, trip flare. The new formulations should meet the criteria of reduced impact, friction, and electrostatic sensitivity as compared with those exhibited by the present system, thus minimizing potential hazards in blending, loading, and assembly operations encountered in production facilities.

ABSTRACT

Markedly safer intermediate and first fire ignition charges were developed for the M49A1 surface, trip flare. The ignition train of the trip flare presently consists of an M42 percussion primer which activates an adjacent intermediate charge (90/10 barium chromate/boron) which, in turn, ignites a pressed first-fire formulation (90/10/1 barium chromate/boron/vinyl alcohol acetate resin) that is in contact with the illuminant load of the flare. Both the present intermediate and first-fire formulations are sensitive to impact, frictional, and electrostatic initiation. If they were to be accidentally initiated during the loading process, they would not only burn, but also cause the subsequent ignition of the illuminant load.

A laboratory study was conducted to develop a substitute formulation closely matching the pressure-time profile and generated gas volume of the presently used compositions, but having significantly less sensitivity. A new formulation containing 65/24/10/1 tungsten/barium chromate/potassium perchlorate/vinyl alcohol acetate resin (VAAR) met these criteria and was demonstrated to be an efficacious substitute for both the older intermediate and first-fire compositions. The new formulation was designated as DP-1886. In addition to the safety factor provided by this change, a reduction of inventory and processing costs will be realized through the use of one formulation for the two different ones currently employed.

CONCLUSIONS

A tungsten formulation DP-1886 (tungsten/barium chromate/potassium perchlorate/VAAR) has been developed which has ignition reliability comparable to that of the standard barium chromate/boron formulations in current use in the M49A1 trip flare. This formulation has the advantage of being less sensitive to impact, friction and electrostatics, thereby decreasing the potential hazards which may be encountered at loading facilities.

RECOMMENDATION

The pertinent technical data package be amended to incorporate the use of DP-1886 as both the intermediate and first-fire formulations.

INTRODUCTION

The ignition train (Fig 1) of the M49A1 trip flare presently consists of an M-42 percussion primer which activates an adjacent intermediate charge (220 mg of 90/10 barium chromate/boron) which in turn ignites a pressed first-fire formulation (6 grams of 90/10/1 chromate/boron/vinyl alcohol acetate resin) that is in contact with an ignition charge (magnesium/sodium nitrate/VAAR); which, again in turn, ignites a three-increment illuminant charge (magnesium/sodium nitrate/Laminac 4116). Both the intermediate and first-fire formulations are sensitive to friction, impact, and electrostatic initiation. If the present first-fire were accidentally initiated during the loading process it would, in turn, ignite the ignition and illumination charges below it. Therefore, a safety advantage would be attained by the substitution of a less sensitive first-fire composition, which would be less likely to be accidentally initiated. Furthermore, if this same new first-fire composition also functioned as the intermediate charge, a further safety advantage as well as a reduction in processing costs would be realized, as indicated above.

RESULTS AND DISCUSSION

At the beginning of the program, a zirconium-nickel alloy formulation similar to those used in hand grenades was introduced. Zirconium-nickel formulations are known to be relatively insensitive to normal stimuli. This initial formulation, SI-295, 35/15/49/2 (70/30) zirconium-nickel alloy/potassium perchlorate/barium chromate/VAAR, had also been previously shown, in a few limited tests, to function as an igniter in the trip flare. The sensitivity of this trip flare formulation as compared with the currently used one is shown in Table 1 (Ref 1, 2).

A loading program was, therefore, initiated in which trip flares were prepared using prepelletized formulations. These were divided into four groups, representing the following intermediate and first-fire compositions:

1. A 90/10 barium chromate/boron intermediate charge (loose powder located in cover assembly) and 90/10/1 barium chromate/boron/VAAR first-fire composition. These are standard production compositions, which were used as controls.

2. A 90/10 barium chromate/boron intermediate charge and SI-295 first-fire composition.

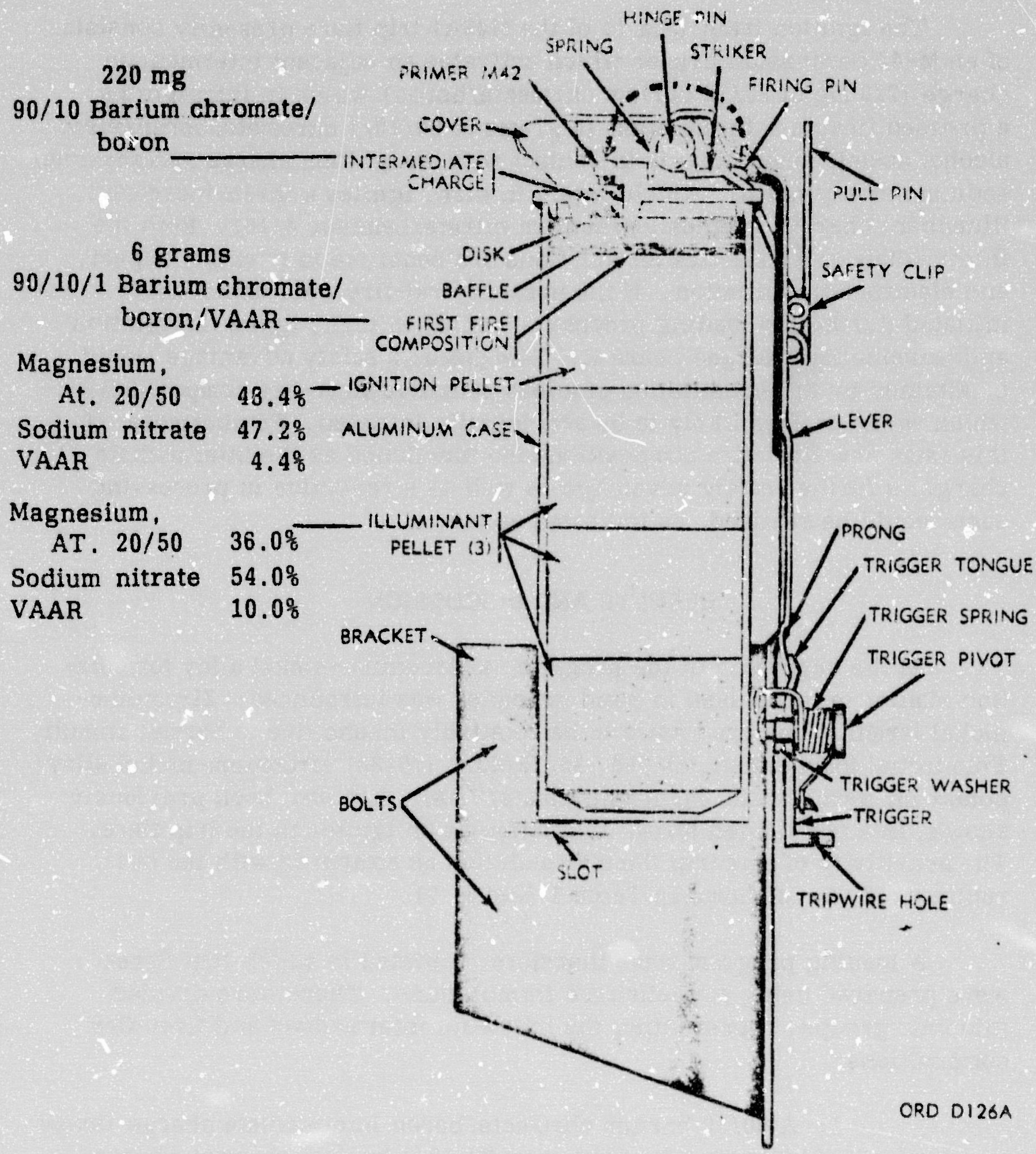

Fig 1 Flare, surface, trip M49A1 (cross sectional view)

Table 1

Comparative sensitivities of the current igniter compositions to that of the SI-295 formulation

Formulation	Friction		Impact	Electrostatic
	Steel Shoe	Fiber Shoe	PA (inches)	(joules)
Current Intermediate Charge DP-906 90/10 barium chromate/boron	Complete burning	Complete burning	12	0.0023
Current First Fire DP-973 90/10/1 barium chromate/boron/VAAR	Complete burning	Complete burning	24	0.025
Selected Replacement SI-295 - 35/15/49/2 70/30 zirconium-nickel alloy/ potassium perchlorate/barium chromate/VAAR	Sparks	No action	29	11.05

3. SI-295 for both intermediate charge and first-fire composition.

4. No intermediate charge and SI-295 first-fire formulation.

The test results are detailed in Table 2.

The 90/10 + 90/10/1 control group produced four nonignitions with cratering-out of composition. These were attributable to inadequate control of assembly procedures. However, significant functioning differences occurred with the use of SI-295 as the first-fire formulation (Group 2); they are attributed to the gas pressure produced upon combustion. The dud rate and cratering-out phenomenon again increased with the substitution of SI-295 for the 90/10 intermediate charge (Group 3), which may be due to the additional quantity of SI-295 and increased pressure buildup produced by the gaseous combustion products of the unconsolidated intermediate charge. The last group was prepared and tested to determine if an intermediate charge was necessary with the use of SI-295 as the first-fire. The results indicated that SI-295 can be initiated directly by the M-42 primer. A small group tested with baffles indicated that they interfered with ignition.

A second loading program was begun, again using prepelletized formulations in which modifications of the SI-295 candidate first-fire formulation were made in order to decrease the amount of gaseous products produced per unit time. This was accomplished by reducing the potassium perchlorate content stepwise from 15 to 14 to 10 percent (SI-295, SI-330, SI-229) as well as reducing the weight of the SI-295 from an initial 6 grams to 4 and 2 grams. Another group of flares was fabricated using loose-fitting cap assemblies to determine if degree of confinement was a factor in nonfunctionings. A final parameter investigated was the oven drying of trip flares at 105°C for 24 hours prior to cap assembly versus no conditioning. All assembled trip flares contained the standard 90/10 barium chromate-boron intermediate charge and cardboard baffle between the intermediate and first-fire formulations. Table 3 details the test results as compared with the present standard 90/10/1 barium chromate/boron/VAAR first-fire formulation.

Groups 1, 2, and 3 represent weight changes in the SI-295 formulation, and give no clear-cut trend except that of a higher functioning level with oven-dried items. Group 4, in which "loose" cap assemblies were

Table 2

Test results of intermediate and first-fire compositions

Group No.	System Intermediate + First Fire	Number Tested	Number Ignited	Non-Ignitions	Number Exhibiting Cratering
1	90/10 + 90/10/1 (with baffle[a])	25	21	4	4
2	90/10 + SI-295 (with baffle)	25	12	13	12
3	SI-295 + SI-295 (with baffle)	25	7	18	9
4	None + SI-295				
	(no baffle)	20	12	8	6
	(with baffle)	5	0	5	2

[a]The baffle consists of a serrated cardboard disc with a center hole, which is inserted between the intermediate and first fire charges to prevent cratering

Table 3

Effect of reduced charge weight, reduced potassium perchlorate content and formulation conditioning on dynamic performance

Group No.	First Fire System	Trip Flares Conditioned at 105°C for 24 Hours Number Functioned/ Number Tested	Trip Flares not Conditioned Before Capping Number Functioned/ Number Tested
1	SI-295 (2 grams) 35/15/49/2 ZrNi/$KClO_4$/$BaCrO_4$/VAAR	3/5	2/4
2	SI-295 (4 grams)	5/5	3/4
3	SI-295 (6 grams)	4/5	3/4
4	SI-295 (6 grams) "Loose" Cap Assembly	5/5	4/4
5	SI-329 (6 grams) 34/10/54/2 ZrNi/$KClO_4$/$BaCrO_4$/VAAR	5/5	0/4
6	SI-330 (6 grams) 29/14/55/2 ZrNi/$KClO_4$/$BaCrO_4$/VAAR	3/5	2/4
7	DP-973 (6 grams) 90/10/1 $BaCrO_4$/B/VAAR	3/3	3/3

made by increasing the ID of the trip flare case, exhibited 100 percent functioning with 6 grams of SI-295 in both conditioned and nonconditioned groups. This indicated that pressure buildup prior to cap release is probably the prime cause of nonfunctioning. A reduction in potassium perchlorate level to 10 and 14 percent (Groups 5 and 6 respectively) was beneficial, with 100 percent functioning as evidenced with SI-329 in an oven-dried condition. The undried counterparts gave much lower levels of functioning. DP-973 (Group 7), the present standard first-fire formulation, functioned perfectly in both conditioned and nonconditioned items.

These results indicated qualitatively that the pressure buildup from the first-fire is the predominant factor leading to poor functioning of the trip flare. It also was apparent that laboratory characterization was required of candidate first-fire formulations versus 90/10/1 barium chromate/boron/VAAR in order to attain the functioning level of the present standard first-fire formulation.

Accordingly, laboratory studies were conducted on SI-295, SI-329, SI-330, and DP-973 to determine pressure-time profiles in 28 ml, 52 ml and 360 ml closed bombs. Also determined were heats of reaction, quantity of gas generated, and ignition temperatures obtained by differential thermal analysis (DTA). The data obtained are shown in Table 4. It can be seen that all the systems are energetic and have approximately the same caloric outputs. The gas volume measurements show the small amount generated per gram by the standard DP-973 relative to the other systems. The high DTA ignition temperature for DP-973 when compared with the other systems appears anomalous, since this material has a rapid time-to-ignition and is very sensitive to most stimuli.

The most important and meaningful data was obtained from closed bomb studies. Time-to-peak pressures and peak pressures obtained with 2.5 gram samples in the various bombs also are shown in Table 4. Figures 2 and 3 illustrate the pressure-time profiles in the two smaller bomb volumes, more typical of the approximate 2 ml free volume above the first-fire composition in the trip flare. Immediately apparent is the difference between the low peak pressure and long time-to-peak pressure profile of the standard DP-973 first-fire; and the markedly higher peak pressures and shorter time-to-peak pressures of the zirconium-nickel alloy groups.

Table 4

Characteristics of zirconium-nickel formulation as compared with standard DP-973

First Fire Designation	SI-330	SI-295	SI-329	Standard DP-973
Zr-Ni Alloy	29	35	34	-
$KClO_4$	14	15	10	-
$BaCrO_4$	55	49	54	90
VAAR	2	2	2	1
B	-	-	-	10
Heat of Reaction, cal/gm	518	553	479	463
Gas Volume, cc/g	70.0	81.3	94.3	29.2
Ignition Temp, °C (DTA)	450	410	430	680
Closed Bomb Data (2.5 g samples)				
Time to peak pressure, msec				
360 ml volume	1040	373	821	388
52 ml volume	212	127	492	396
28 ml volume	79	47	103	15.8, 110 (two peaks)
Peak pressure, psi				
360 ml volume	29	60	40	14
52 ml volume	439	540	366	57
28 ml volume	746	757	671	74, 96 (two peaks)

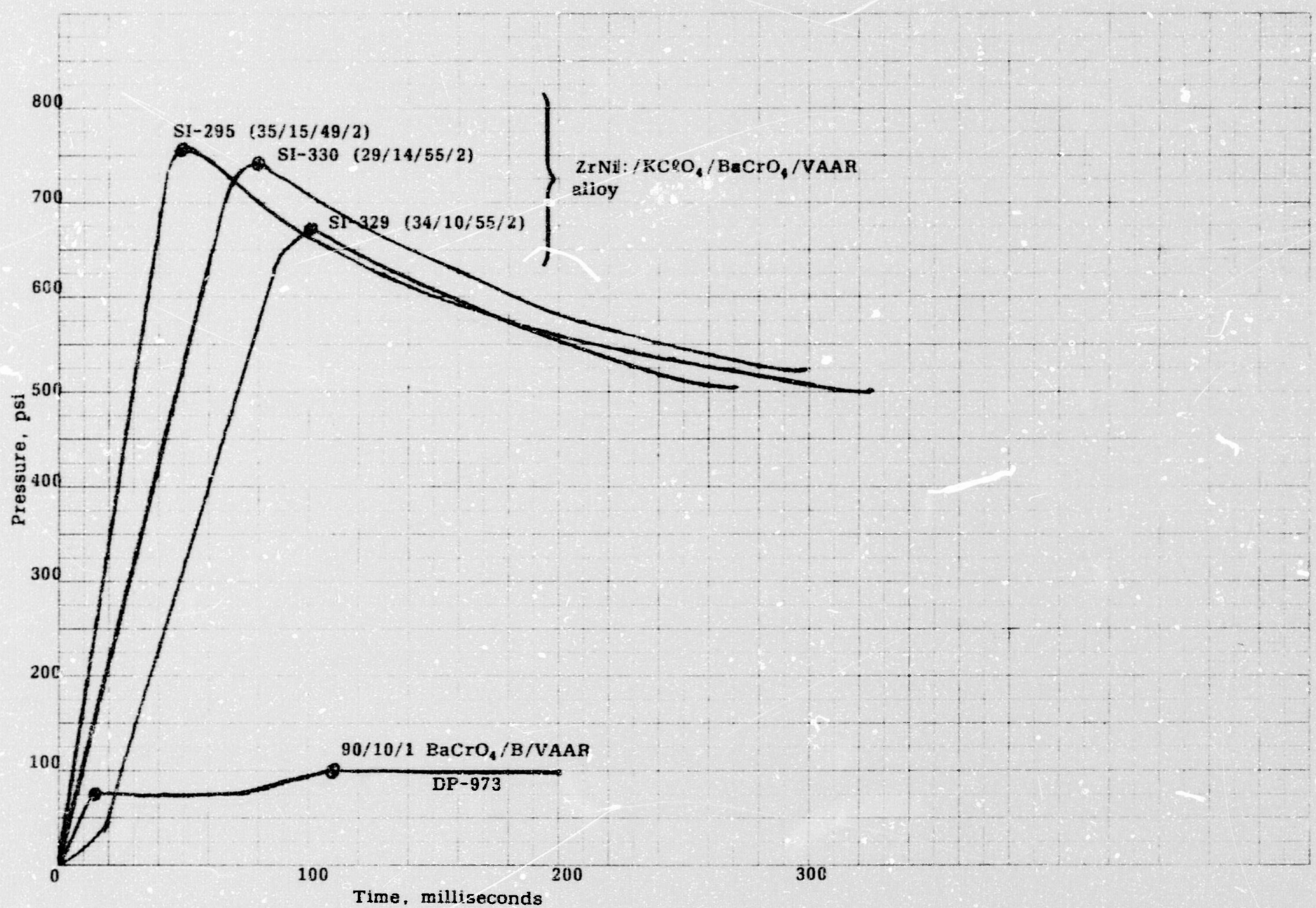

Fig 2 Pressure - time profiles of zirconium-nickel formulations vs barium chromate/boron/VAAR in 28 ml volume, 2.5 gram samples

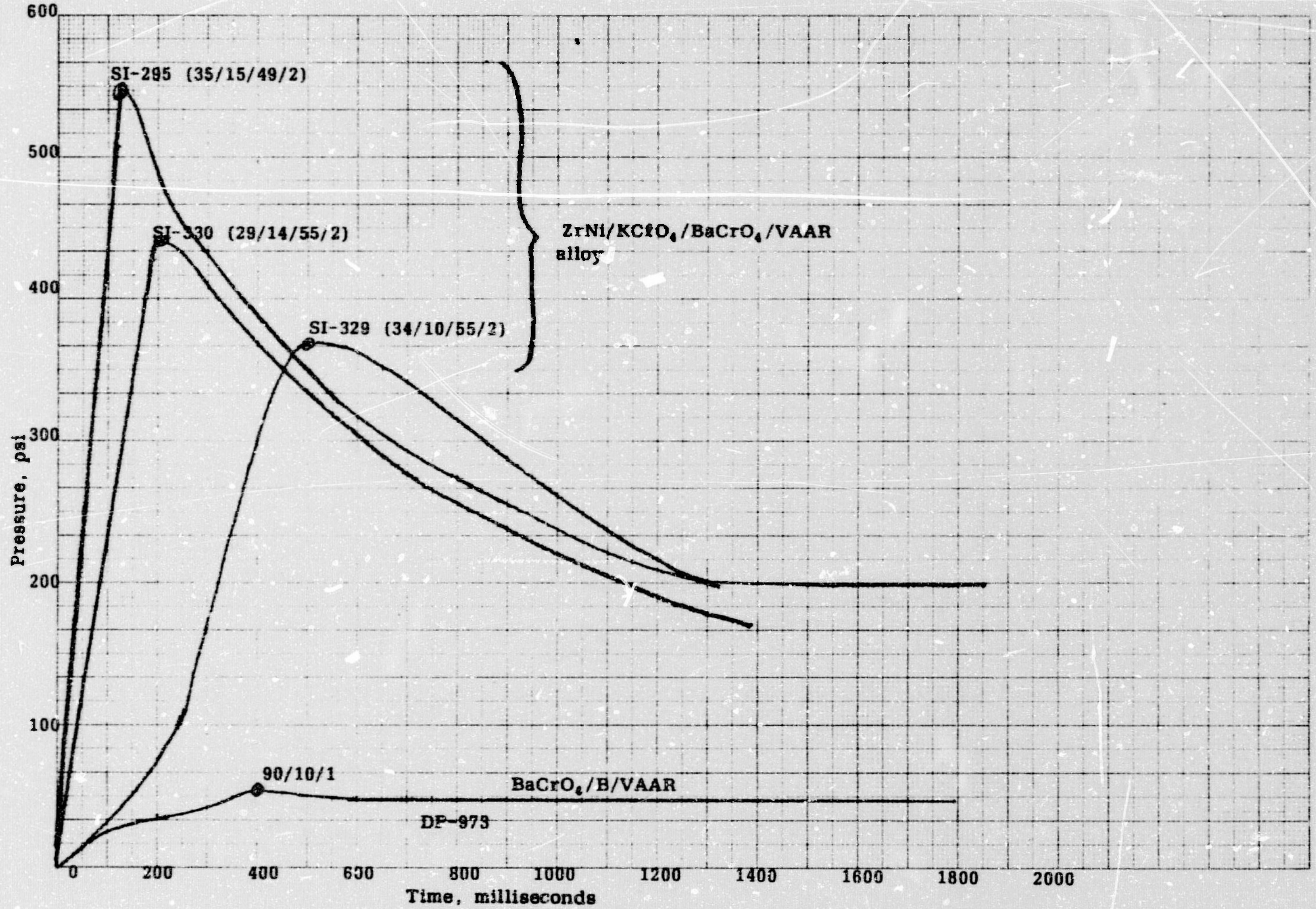

Fig 3 Pressure - time profiles of zirconium-nickel formulations vs barium chromate/boron/VAAR in 52 ml volume, 2.5 gram samples

The closed bomb and gas volume data indicate that an efficacious substitute for 90/10/1 barium chromate/boron/VAAR (DP-973) would be a slow-burning composition producing the minimum volume of gas necessary to blow off the trip flare cap. The gas pressure developed may be due to igniter functioning and/or flare ignition. Measurements made by the end-item engineers showed that 100 to 170 psi is required to dislodge the covers from trip flares. If the igniter produces a high pressure pulse forcing off the cover, a transient vacuum is created above the first-fire surface, resulting in either the quenching of the first-fire burning and/or a cratering-out of the first-fire and ignition pellet composition.

In line with the above criteria, groups of trip flares were loaded with SI-329 first-fire at 6 and 4 gram levels, as well as modifications of SI-329 in which the gas producing ingredient, potassium perchlorate, was reduced from 10 to 8 and 6 percent, respectively (SI-332, SI-331). Also investigated were new low gas-producing candidate formulations based on aluminum, titanium, and 70/30 zirconium-nickel alloy as fuels, molybdenum trioxide as oxidant, and sodium fluoride as a propagation aid with VAAR binder at the 6 gram level (SI-335, SI-333, SI-334). Standard DP-973 first-fire was carried along as a control. All flares were conditioned at 105°C for 24 hours before capping. The functioning data is given in Table 5.

The results of these tests were inconclusive; i.e., both the reduction of the quantity of SI-329 from 6 to 4 grams, and that of the potassium perchlorate content of the formulation failed to produce the 100 percent of functioning level of the standard first-fire formulation. Of the molybdenum trioxide systems, only SI-333 produced 100 percent functionings, and even these were characterized by violent processes with extremely high sound levels occurring on cap separation. Subsequent closed bomb tests of the SI-333 formulation (Fig 4) showed that this sytem produces less pressure and at a slower rate than the standard boron/barium chromate/VAAR first-fire formulation. These tests clearly demonstrate that although pressure-time signatures generated by the igniter play an important role in the proper trip flare functioning, other factors also may be important. They may include transfer of thermal energy to the illuminant composition, thus providing rapid or slow generation of pressure due to products of the magnesium/sodium nitrate reaction.

Still pursuing the theory that an energetic igniter system producing minimal gas was necessary, a new system was investigated. This system, DP-1886, consists of 65/24/10/1 tungsten/barium chromate/potassium

Table 5

Dynamic performance of zirconium-nickel, aluminum and titanium formulations as compared with standard barium chromate/boron/VAAR

Group No.	First Fire System	Number Functioned/Number Tested	Percentage Functioned
1	DP-973 (6 grams) 90/10/1 $BaCrO_4$/B/VAAR	8/8	100%
2	SI-329 (6 grams) 34/10/54/2 ZrNi/$KClO_4$/$BaCrO_4$/VAAR	5/7 (2 nonignitions)	72%
3	SI-329 (4 grams)	7/9 (2 cratered out)	77%
4	SI-332 (6 grams) 35/8/55/2 ZrNi/$KClO_4$/$BaCrO_4$/VAAR	8/10 (2 nonignitions)	80%
5	SI-331 (6 grams) 36/6/56/2 ZrNi/$KClO_4$/$BaCrO_4$/VAAR	6/10 (4 nonignitions)	60%
6	SI-335 (6 grams) 25/68/5/2 Al/MoO_3/NaF/VAAR	2/4 (2 nonignitions) very violent functioning	50%
7	SI-334 (6 grams) 38/55/5/2 ZrNi/MoO_3/NaF/VAAR	0/4 (4 nonignitions)	0%
8	SI-336 (6 grams) 31/62/5/2 Ti/MoO_3/NaF/VAAR	5/5 very violent functioning	100%

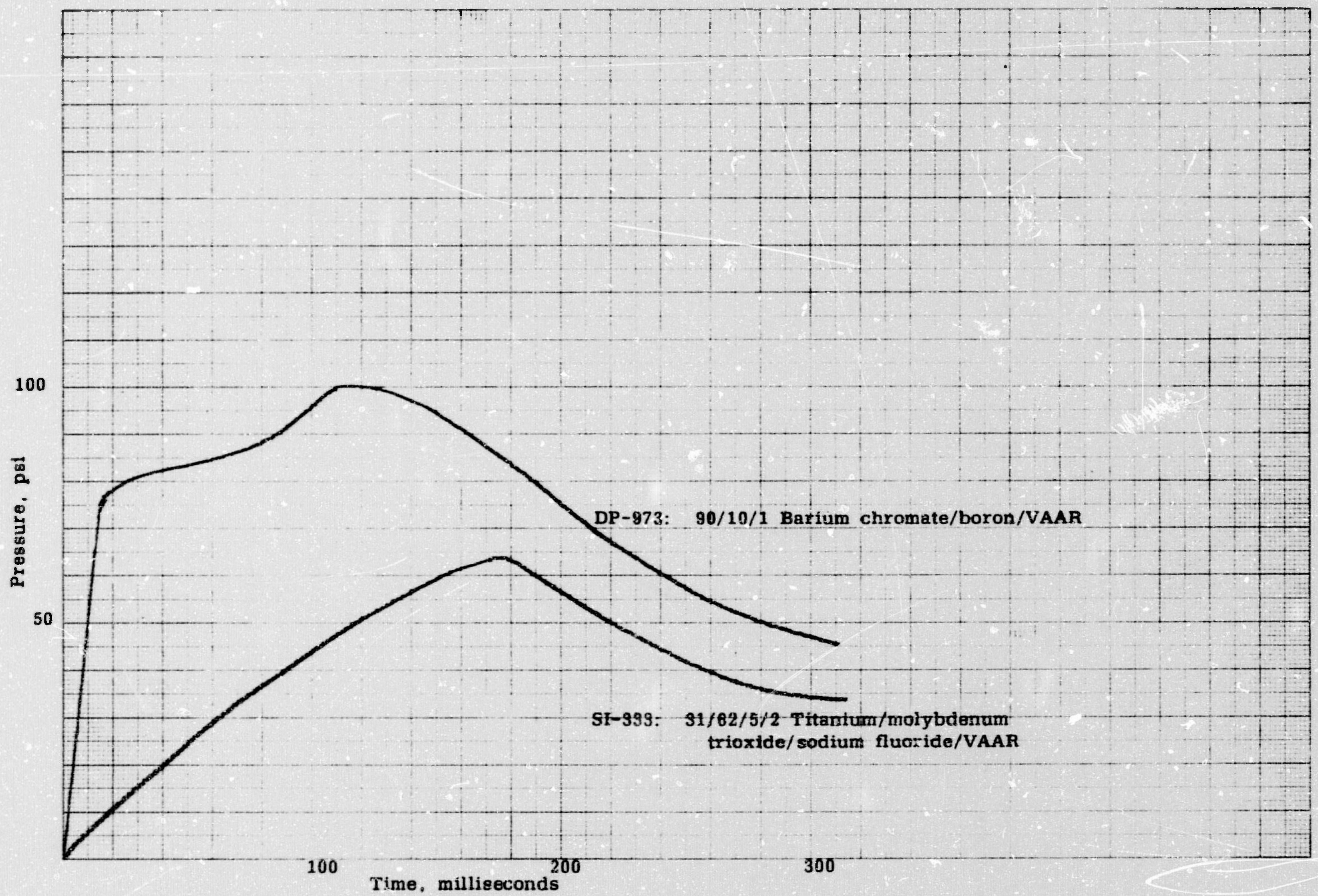

Fig 4 Pressure - time profiles: SI-333 and DP-973 in 28 ml volume, 25 gram samples

perchlorate/VAAR; and although it contains potassium perchlorate it is near stoichiometric and should not produce quantities of gas like the oxygen-rich zirconium-nickel alloy/potassium perchlorate/barium chromate/VAAR system. Table 6 shows the closed bomb gas evolution data for this system together with some of the previous systems. All of these tests employed DP-906 (90/10 barium chromate/boron) as the intermediate charge. The results show that the tungsten system most closely matched the pressure and time-to-peak pressure of the standard first-fire formulation, and also produced the least gas. Two failures were encountered with the tungsten system, but they were attributed to the high density of the composition, which resulted in poor surface coverage using 6 grams. As to the highly energetic titanium system, it produced 100% functioning but still caused violent cap ejection.

At this point in the program, tools for direct loading of loose powder into the trip flare cases were fabricated and the loading program above was duplicated using this procedure. It should be noted that the specification for loose powder loading calls for consolidation at 10,000 psi as compared to 5,000 psi as with pellet loading. The charge weight of the DP-1886 was increased to 8 and 10 gram levels to obtain adequate coverage. The results, all obtained under ambient conditions, are tabulated in Table 7. The increased loading pressure decreased the burning rate, resulting in loud but not violent ignition of the titanium (SI-340) formulation. The zirconium-nickel formulation still appeared marginal with only 80% functioning. Satisfactory (100%) functioning was achieved with the tungsten (DP-1886) at both the 8 gram and 10 gram charge weight.

Based on the results of that test series, and because of the excellent storage and compatibility properties of tungsten delay systems (tungsten igniter and delay systems employ the same ingredients but at different percentage levels), it was decided to proceed with DP-1886 (8 grams) as the best first-fire candidate. A loading program was initiated for dynamic tests at both ambient and, after conditioning, at -65°F. Concurrently, an evaluation of the DP-1886 with and without VAAR as a substitute for the standard 90/10 barium chromate/boron intermediate charge (DP-906) was conducted. Performance results are shown in Table 8.

Before proceeding with further studies of the tungsten system, the DP-1886 composition was tested as to its sensitivity to friction, impact, and electrostatics. The results of these tests are given in Table 9

Table 6

Closed bomb and dynamic test results of additional candidate first-fire formulations

Group	First Fire System	Dynamic Test Number Functioned/ Number Tested	Closed Bomb Test, 28 ml Pressure psi	Time to Peak millisec	Residual Gas ml/g
1	DP-973 (6 grams)	21/21	131.3	175-325	45.3
	90/10/1 $BaCrO_4$ B/VAAR	Mild functioning			
2	SI-332 (6 grams)	19/22	337.5	200	83.6
	35/8/55/2 Zr-Ni/ $KClO_4$/$BaCrO_4$/VAAR	Mild functioning	Results for 10% $KClO_4$ formulation		
3	SI-340 (6 grams)	21/21	172.5	475-525	45.0
	33/65/2 Ti/MoO_3/ VAAR	Violent functioning			
4	DP-1886 (6 grams)	19/21	100-125	100-125	11.7
	65/24/10/1 W/$BaCrO_4$ $KClO_4$/VAAR	Mild functioning			

Table 7

Dynamic results of candidate first-fire formulations fabricated by loose-powder procedure

Group	First Fire System	Number Functioned/ Number Tested	Percent Functioned
1	DP-973 (6 grams)	10/10	100%
	90/10/1 $BaCrO_4$/B/VAAR	Mild functioning	
2	SI-332 (6 grams)	8/10	80%
	35/8/55/2 Zi-Ni/$KClO_4$/ $BaCrO_4$/VAAR	Ignition slow	
3	SI-340 (6 grams)	10/10	100%
	33/65/2 Ti/MoO_3/VAAR	Somewhat loud, not violent	
4	DP-1886 (8 grams)	10/10	
	65/24/10/1 W/$BaCrO_4$/ $KClO_4$/VAAR	Mild functioning	100%
5	DP-1886 (10 grams)	10/10 Mild functioning	100%

Table 8

Comparative evaluation of DP-906 and DP-1886

Ignition System	Test Condition	Number Tested/Number Functioned	Percent Functioned
Intermediate DP-906 First Fire DP-1886	Ambient -65°F	10/10 10/10	100% 100%
Intermediate DP-1886 First Fire DP-1886	Ambient	9/9	100%
Intermediate DP-1886 (no VAAR) First Fire DP-1886	Ambient	5/5	100%

Table 9

Comparison of sensitivity and physico-chemical characteristics of DP-906, DP-973 and DP-1886

	DP-906	DP-973	DP-1886
Sensitivity			
Friction: Steel Shoe	Complete Burning	Complete Burning	No Action
Fiber Shoe	Complete Burning	No Action	No Action
Impact, PA, inches	12	24	33
Electrostatics, min joules	0.0023	0.025	0.749
Heat of Reaction, cal/g	515	463	249
Gas Volume, cc/g	3.1	29.2	16.1
Ignition Temperature, DTA	560°C	680°C	421°C
Closed Bomb Data			
Time to Peak, msec			
360 ml bomb	-	388	198
52 ml bomb	-	396	166
28 ml bomb	112.4	15.8, 110 Two Peaks	100-125
Peak Pressure, psi			
360 ml bomb	-	14	9.3
52 ml bomb	-	57	37.9
28 ml bomb	44.4	74, 96 Two Peaks	100-125

Notes:

DP-906 Current standard intermediate charge 90/10 barium chromate/boron

DP-973 Current standard first fire 90/10/1 barium chromate/boron/VAAR

DP-1886 New intermediate and first fire charge 65/24/10/1 tungsten/barium chromate/potassium perchlorate/VAAR

together with other pertinent physico-chemical data (Ref 3 and 4). The pressure-time profile of the tungsten system is compared with that of the standard barium chromate/boron/VAAR system in Figure 5. It can be seen that the two systems reach peak pressures at about the same time.

On the basis of these highly satisfactory results, an ignition system utilizing DP-1886 as both the first fire (8 grams) and intermediate charge (400 milligrams) was finalized. A confirmatory loading program consisting of 40 items was initiated and completed. The items were tested after being subjected to conditioning as indicated in Table 10.

In the final test phase, 300 complete rounds were loaded and assembled with the final first-fire and intermediate charge DP-1886. These items together with production controls were subjected to engironmental conditioning in accordance with a test program (Ref 5) prepared in coordination with the Product Assurance Directorate. The items, after appropriate conditioning, were functioned for ignition reliability, and their burning times were recorded. The individual results are tabulated in Tables 11, 12, 13, and 14. Summarized results are recorded in Tables 15, 16, 17, and 18. The results show very satisfactory performance, with only one failure in the 7-day temperature-and-humidity group. That failure is attributed to a faulty seal; all items conditioned for two weeks functioned. No effect on burning times obtained could be attributed to the effects of the ignition systems, since essentially all items were above the minimum burning time requirement (55 seconds) and comparable to the production controls.

Vacuum stability tests (90°C for 40 hours) were conducted to determine if any incompatibility would exist between the new first-fire and the illuminant increment (FY1544). The test results show no significant amount of gas evolution, thus indicating no incompatibility. The results are as follows: (Ref 6):

DP-1886	0.14 ml
FY-1544	0.10 ml
50/50 DP-1886/FY1544	0.06 ml

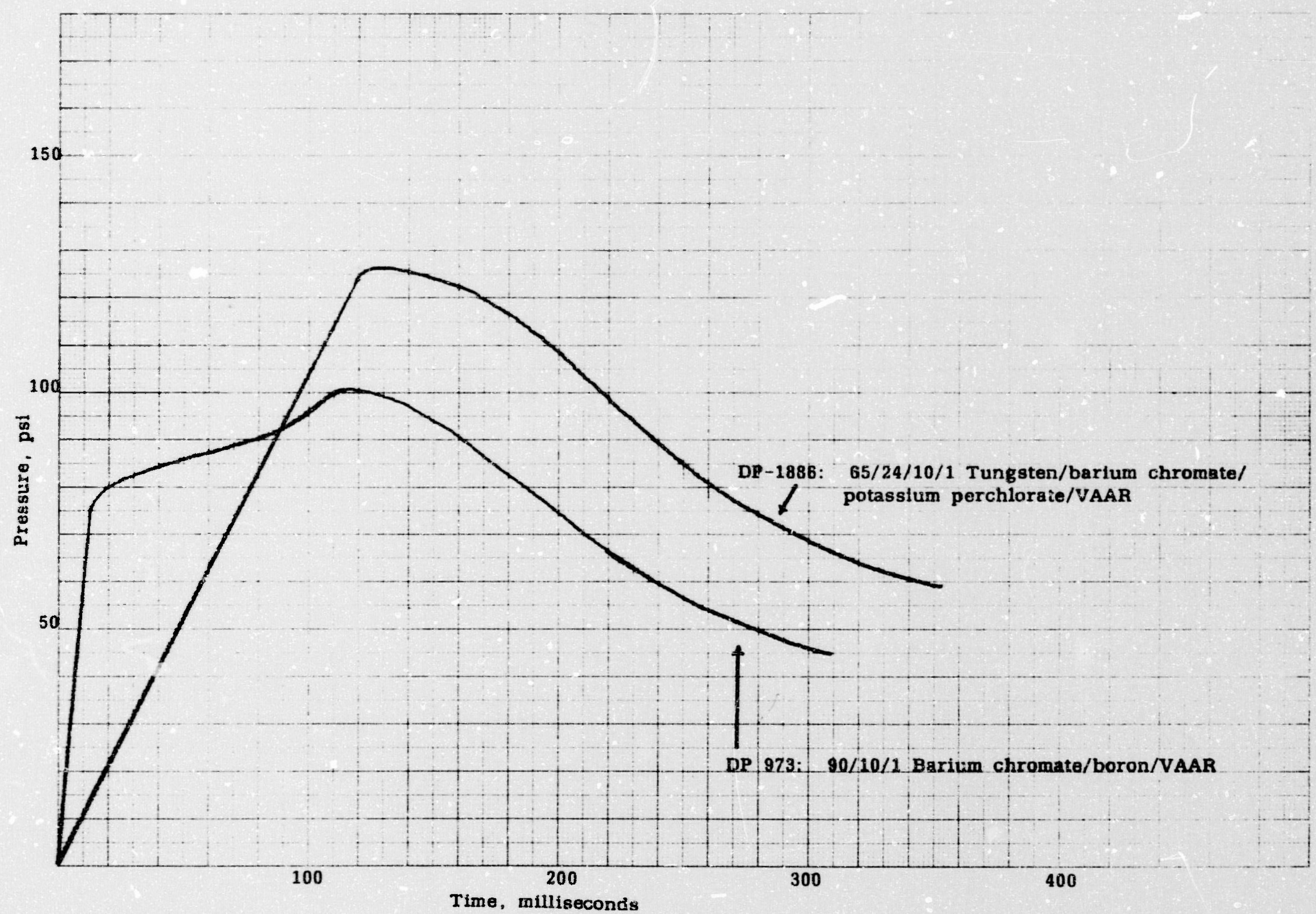

Fig 5 Pressure - time profiles: DP-1886 and DP-906 in 28 ml volume, 25 gram samples

Table 10

Conditioning of 40 test items

Number Tested	Conditioning	Number Functioned	Percent Functioned
10	Ambient	10	100%
10	24 hrs -65°F fired cold	10	100%
10	24 hrs +165°F fired hot	10	100%
10	20 minute jumble	10	100%

Table 11

Factorial test program, burning times (seconds)

	Tested Ambient				Tested Cold (-65°F)				Tested Hot (+165°)			
	Production Controls		Test Items		Production Controls		Test Items		Production Controls		Test Items	
	T&H	No T&H	T&H	No T&H	T&H	No T&H	T&H	No T&H	T&H	No T&H	T&H	No T&H
Transportation-Vibration	57	68	68	67	64	67	(NBT)[a]	74	69	(NBT)[a]	75	72
	60	(NBT)[a]	66	67	78	72	(NBT)[a]	72	68	73	(NBT)[a]	(NBT)[a]
	58	68	74	73	71	73	71	(NBT)[a]	65	(NBT)[a]	60	73
	65	(NBT)[a]	63	78	64	68	66	(NBT)[a]	57	66	68	69
	61	61	77	69	65	69	(BT)[a]	65	59	64	68	64
	62	61	(NBT)[a]	66	66	62	66	63	62	66	66	69
	61	72	68	62	64	68	68	72	60	64	70	(NBT)[a]
	61	65	69	68	73	(NBT)[a]	(NBT)[a]	63	63	(NBT)[a]	68	(NBT)[a]
No Transportation-Vibration	66	74	64	58	66	66	67	66	(NBT)[a]	68	68	72
	61	73	(NBT)[a]	66	68	64	66	76	(NBT)[a]	58	71	60
	67	68	66	68	74	70	68	72	58	60	62	64
	68	55	66	64	(NBT)[a]	(NBT)[a]	64	70	(NBT)[a]	66	62	58
	(NBT)[a]	59	71	60	(NBT)[a]	70	64	(NBT)[a]	(NBT)[a]	63	64	64
	53	64	64	58	64	70	69	63	75	67	61	73
	68	61	64	67	67	64	70	67	56	66	61	(NBT)[a]
	71	65	62	66	64	66	67	74	59	66	60	69

[a] (NBT): Item functioned. No burning time recorded.

Table 12

Jumble box, burning times (seconds)

20 Minutes			Two Hours	
Production Controls	Test Items		Production Controls	Test Items
59	77	76	72	72
62	72	64	67	62
64	66	64	65	(NBT)[a]
68	68	75	64	(NBT)[a]
64	62	73	68	74
66	71	61	63	62
71	70	75	64	64
72	63	77	63	(NBT)[a]
(NBT)[a]	68	66	71	72
65	75	70	66	64
	67	75		
	73	73		
	70	70		
	68	65		
	76	60		

[a] (NBT): Item functioned. No burning time recorded.

Table 13

Long term temperature and humidity, burning times (seconds)

7 Days		14 Days	
Production Controls	Test Items	Production Controls	Test Items
82	79	69	71
57	71	(NBT)[a]	67
69	71	72	64
70	68	64	72
67	71	68	(NBT)[a]
77	60	71	69
54	68	64	64
63	64	(NBT)[a]	64
61	79	64	64
68	No Function	68	66
	71		66
	70		68
	78		64
	64		67
	69		68
	69		66
	60		62
	71		66
	75		73
	70		(NBT)[a]

[a] (NBT): Item functioned. No burning time recorded.

Table 14

Long term storage surveillance, burning times (seconds)

	1 Week		2 Weeks		3 Weeks		4 Weeks	
	Production Controls	Test Items	Production Controls	Test Items	Production Controls	Test Items	Production Controls	Test Items
	65	82	-	83	-	71	70	70
A	73	70	-	82	-	74	71	70
M	69	78	-	70	-	71	72	70
B	(NBT)[a]	81	-	70	-	63	65	66
I	75	68	-	76	-	64	71	66
E	68	64	-	63	-	65	59	60
N	59	69	-	75	-	75	68	74
T	70	80	-	77	-	74	(NBT)[a]	(NBT)[a]
	64	71	-	77	-	65	66	76
	57	75	-	90	-	71	62	75
	64	72	-	74	-	74	72	71
	67	70	-	65	-	74	63	63
H	66	74	-	77	-	75	65	71
O	67	75	-	72	-	72	60	73
T	(NBT)[a]	68	-	72	-	67	64	68
	60	70	-	73	-	71	60	60
(+165° F)	72	72	-	76	-	64	(NBT)[a]	57
	62	(NBT)[a]	-	69	-	75	64	68
	65	70	-	(NBT)[a]	-	75	60	68
	67	62	-	70	-	71	(NBT)[a]	64

Table 14 (Cont'd)

	Production Controls	Test Items	Production Controls	Test Items	Production Controls	Test Items	Production Controls	Test IItems
	75	74	-	74	-	59	71	70
	61	87	-	76	-	74	(NBT)[a]	71
C	66	65	-	78	-	73	60	77
O	71	70	-	74	-	80	63	72
L	69	73	-	70	-	72	62	73
D	73	66	-	63	-	71	75	69
	63	67	-	65	-	70	72	73
(-65^{o}F)	60	69	-	73	-	79	68	67
	(NBT)[a]	67	-	71	-	74	58	76
	75	64	-	73	-	76	(NBT)[a]	75

[a] (NBT): Item functioned - no burning time recorded

Table 15

Factorial test summary

		Tested Ambient				Tested Cold ($-65^{o}F$)				Tested Hot ($+165^{o}F$)			
		Production Controls		Test Items		Production Controls		Test Items		Production Controls		Test Items	
		T&H	No T&H	T&H	No T&H	T&H	No T&H	T&H	No T&H	T&H	No T&H	T&H	No T&H
Transportation-Vibration	Number Items Tested	8	8	8	8	8	8	8	8	8	8	8	8
	Number Items Functioned	8	8	8	8	8	8	8	8	8	8	8	8
	Minimum Burning Time, seconds	57	61	63	62	64	62	66	63	57	64	60	64
	Maximum Burning Time, seconds	65	72	77	78	78	73	71	74	68	73	75	73
	Average Burning Time, seconds	60.6	65.0	69.3	69.0	68.1	68.4	67.8	68.2	62.9	66.6	67.9	69.0
No Transportation-Vibration	Number Items Tested	8	8	8	8	8	8	8	8	8	8	8	8
	Number Items Functioned	8	8	8	8	8	8	8	8	8	8	8	8
	Minimum Burning Time, seconds	53	55	52	58	64	64	64	63	56	58	60	58
	Maximum Burning Time, seconds	71	74	71	68	74	70	70	76	75	68	71	73
	Average Burning Time, seconds	64.9	64.9	65.3	63.4	67.2	67.1	66.9	69.7	62.0	64.3	63.6	65.7

Table 16

Jumble box test summary

	20 Minutes		2 Hours	
	Production Controls	Test Items	Production Controls	Test Items
Number Items Tested	10	20	10	10
Number Items Functioned	10	20	10	10
Minimum Burning Time, seconds	59	61	63	62
Maximum Burning Time, seconds	72	77	72	74
Average Burning Time, seconds	65.7	69.7	66.3	67.1

Table 17

Long term temperature and humidity summary

	7 Days		14 Days	
	Production Controls	Test Items	Production Controls	Test Items
Number Items Tested	10	20	10	20
Number Items Functioned	10	19	10	20
Minimum Burning Time, seconds	54	60	64	62
Maximum Burning Time, seconds	82	79	72	73
Average Burning Time, seconds	66.8	69.9	67.5	66.7

Table 18

Long term storage surveillance summary, burning times (seconds)

		1 Week		2 Weeks		3 Weeks		4 Weeks	
		Production Controls	Test Items	Production Controls	Test Items	Production Controls	Test Items	Production Controls	Test Items
Ambient	Number Items Tested	10	10	0	10	0	10	10	10
	Number Items Functioned	10	10	-	10	-	10	10	10
	Minimum Burning Time, seconds	57	70	-	70	-	63	59	60
	Maximum Burning Time, seconds	75	82	-	83	-	75	72	76
	Average Burning Time, seconds	67.0	72.8	-	76.3	-	69.3	67.0	69.7
Hot (+165^{o}F)	Number Items Tested	10	10	0	10	0	10	10	10
	Number Items Functioned	10	10	0	10	-	10	10	10
	Minimum Burning Time, seconds	60	62	-	65	-	64	60	57
	Maximum Burning Time, seconds	72	75	-	77	-	75	72	73
	Average Burning Time, seconds	65.4	70.3	-	72.0	-	71.8	63.5	66.4
Cold (-65^{o}F)	Number Items Tested	10	10	0	10	-	10	10	10
	Number Items Functioned	10	10	-	10	-	10	10	10
	Minimum Burning Time, seconds	60	64	-	63	-	59	58	67
	Maximum Burning Time, seconds.	75	74	-	74	-	80	75	77
	Average Burning Time, seconds	68.1	70.0	-	70.7	-	72.8	68.6	72.3

EXPERIMENTAL PROCEDURE

Blending

The compositions which did not contain a binder were prepared in accordance with Sequence of Operation PC-5 and PC32. The formulations which contained a binder, such as VAAR or Laminac, were blended in accordance with Sequence of Operation PC-4.

Loading

Cover Assemblies

Primers were seated using 250 ± 10 lb dead load. Intermediate charge was loosely loaded and sealed in accordance with Drawing No. 8836964.

Illuminant and First Fire Charge

Loose powder loaded in accordance with Drawing No. 9269017.

Pelletized illuminant loaded in accordance with Drawing No. 8836967.

Complete Illuminant Assembly

Procedure in accordance with Drawing No. 8836957.

Testing Procedures

Transportation - Vibration

In accordance with MIL-STD-331, Test 119, Procedure 1, dated 1 May 1973. All items tested in package.

Temperature Conditioning (Functional)

All items conditioned 16 hours prior to testing and fired at the conditioned temperature.

Temperature and Humidity

In accordance with MIL-STD-331 except that candle-power readings were waived.

Jumble Test

In accordance with MIL-STD-331 Test 102 and also at specified durations.

Long-Term Temperature Surveillance

For durations and temperatures indicated. All tested at ambient.

Materials:

Magnesium, At. 20/50, 450 + 50, MIL-P-14067A, Hart Metals Corporation

Sodium Nitrate, 32 ± 15 μ, MIL-S-322C, Davies Nitrate Corporation

Laminac, 4116, American Cyanamide Corporation

Vinyl Alcohol Acetate Resin, MA-28-18, Palmer Products

Zirconium-Nickel Alloy - 70/30, 4.3 μ, MIL-Z-11410B, Ventron Corporation

Aluminum, At., 6 μ, MIL-A-512, Aluminum Corporation of America

Barium Chromate, 1 μ, MIL-B-550A, Fisher Scientific Corporation

Tungsten Powder, 4.5 μ, MIL-T-48140, General Electric Corporation

Titanium Powder, 10 μ, MIL-T-13405, Metal Hydrides Corporation

Potassium Perchlorate, 22 μ, MIL-P-217A, Western Electric Corporation

Boron, 1 μ, MIL-B-51092, Woodridge Chemical Company

Sodium Fluoride, reagent grade, J. T. Baker Chemical Company

Molybdenum Trioxide, reagent grade, J. T. Baker Chemical Company

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2. Test Report 335.71, Experimental Evaluation Division, Technical Services Directorate, September 1971

3. Laboratory Report No. 73-FR-G-R-2/3, Propellants Research Branch, Propellants Division, FRL, 10 April 73

4. Test Report, informal, Experimental Evaluation Division, Technical Services Directorate, 15 May 1973

5. DF from ASR&D, PAD to Ch, Pyro Div, dtd 3 Dec 1971 and 10 May 1973

6. Laboratory Report No. AL-S-124-73, Analytical Chemical Branch, Propellants Division, FRL, 23 July 1973